Seattle Public Utilities

Memorandum

Date: May 15, 2008, **Updated January 14, 2009**

To: Tracy Tackett, PE, LID Program Manager

From: Shanti Colwell, PE, Environmental Engineer
Jeff Fowler, PE, Geotechnical Engineering Supervisor

Re: **Updated** SPU Bioretention Soil - Modeling Inputs and Water Quality Treatment

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This memorandum has been updated to reflect changes that address Ecology's concerns and make the City of Seattle's Standard Specification for Bioretention Soil consistent with Washington State University's Technical Memorandum, "Bioretention Soil Mix Review and Recommendations for Western Washington", dated December 2008. The changes are bolded.

Seattle Public Utilities (SPU) has updated our bioretention soil specification for turf and landscaped areas dated **January 27, 2009** (Appendix A). To accomplish this, we gathered input from experts on soils, compost, and aggregate within SPU and around the region. A specification was developed that could be easily met by contractors and homeowners, while also meeting the plant survivability and growth needs and facility infiltration and treatment goals of bioretention technologies within the City of Seattle.

This memorandum provides SPU's recommendations and justifications for modeling inputs for the bioretention soil and discusses how it meets Washington State Department of Ecology's (Ecology) requirements for treatment.

MODELING INPUTS

For this specification to be used in design of bioretention technologies, modeling inputs for infiltration rate and porosity need to be provided. Table 1 provides SPU's modeling recommendations.

Infiltration Rate

The short-term infiltration rate for both the landscape and turf bioretention soils were approximated based on lab and field testing and is shown in Table 2. Initially, SPU looked at lab testing information from testing of other bioretention soils with similar aggregate/compost mixes and percent compaction, compiled in a study by Shannon and Wilson dated March 2007 (attached) for SPU. As illustrated by the range of permeability values in Table 1 of the attached Shannon and Wilson report, the infiltration rate is highly variable. Based on further discussion and review of the tested soils compared to our new bioretention soil specification, it was determined that only the samples identified as January 06, SPU Testing, 65/35 (testing of the Pinehurst Natural Drainage System bioretention soils) and WSU testing were appropriate to include in Table 2 for evaluation of a design infiltration rate. This table also includes additional laboratory testing information from Washington State University's testing of bioretention soils (Hinman, 2008). Field results from two controlled infiltration tests at High Point were also included in Table 2. The data

reports from both of the High Point infiltration tests are also attached. All laboratory permeability testing was done in accordance with ASTM D2434, and the field tests were done in accordance with DOE's pilot infiltration test guidance.

Because of the high variability in permeability illustrated in the Shannon and Wilson report for soils of similar compaction and a lack of data comparing the infiltration rates of water compacted bioretention soil and 85% compacted bioretention soil, the recommended design infiltration rate shown in Table 2 is the same for both the landscape and turf bioretention soil.

The short-term infiltration rate with the appropriate long-term correction factor applied is the value that SPU recommends for modeling facilities using our bioretention soil specification. The change in the short-term infiltration rate over the long term will vary based on site conditions, the type of sediment loading that the bioretention facility receives, and whether or not an underdrain is present, which is why the correction factor value varies based on the characteristics of the water flowing into the cell. SPU follows the recommendations of the Puget Sound Action Team (PSAT) and Ecology for cells without underdrains as a conservative estimate of how the facility will perform in the long term. For facilities with underdrains, SPU will limit the amount of flow to each cell and recommend a correction factor of 2.

Table 1. Recommendations for Bioretention Soil Infiltration Rate and Porosity

			Long-term Correction Factor		
Bioretention Soil Type	Compaction	Short-term Infiltration Rate, in/hr	> 5,000 sf pgs; > 10,000 sf impervious surface; or > ¾ acre lawn and landscape*	< 5,000 sf pgs; < 10,000 sf impervious surface; or < ¾ acre lawn and landscape*	Porosity, %
Landscape **w/o** underdrain	**80-85**	**6 (+ 7, - 5)**	4	2	40 ± 10
Turf **w/o** underdrain	**85-90**	**6 (+ 7, - 5)**	4	2	40 ± 10
Landscape **w/** underdrain	**80-85**	**6 (+ 7, - 5)**	NA – exceeds permissible limits for cells with underdrains	2	40 ± 10
Turf **w/** underdrain	**85-90**	**6 (+ 7, - 5)**	NA – exceeds permissible limits for cells with underdrains	2	40 ± 10

* Consistent with PSAT 's "Low Impact Development Technical Guidance Manual for Puget Sound", January 2005, which includes DOE's bioretention soil flow modeling guidance.

Porosity

A theoretical analysis using soil phase diagrams of the bioretention soil was completed by SPU's Geotechnical Laboratory to develop an approximate range of porosity values. The density of the aggregate and compost were varied within ranges provided by Manufacturer's of the aggregate and compost and the resulting porosity ranged from 30 to 50 percent. The mean value of this range is presented in Table 1.

Revisions to the October 10, 2008 Stormwater Manual Submittal– Volume 3, Chapter 4

The revisions below are recommended to the Stormwater Manual Submittal that went to Ecology on October 10, 2008.

- ***Section 4.4.1.2 Bioretention Cell – Design Criteria – Bioretention Soil – Table 4.9 (p. 4-41)*** – **Replace Table 4.9 with the following:**

Bioretention Soil Type	Compaction (%)	Short-term Infiltration Rate, (inch/hour)	Design Infiltration Rate (inch/hour)	
			Drainage Area < 5,000 sf pgs; < 10,000 sf impervious surface; or < ¾ acre lawn and landscape	Drainage Area> 5,000 sf pgs; > 10,000 sf impervious surface; or > ¾ acre lawn and landscape
Long-term Infiltration Rate Correction Factor			2	4
Landscape without underdrain	**80-85**	**6**	**3**	**1.5**
Turf without underdrain	**85-90**	**6**	**3**	**1.5**
Landscape with underdrain	**80-85**	**6**	**3**	NA – exceeds permissible limits for cells with underdrains
Turf with underdrain	**85-90**	**6**	**3**	NA – exceeds permissible limits for cells with underdrains

- ***Section 4.4.1.2 Bioretention Cell – Design Criteria – Underdrain (p. 4-42)*** – Insert the following bullet: "The maximum area flowing to each cell with an underdrain must be <5,000 sf pgs; <10,000 sf impervious surface; or <¾ acre lawn and landscape."
- ***Section 4.4.1.2 Bioretention Cell – BMP Sizing – Facility Modeling – Table 4.11 (p.4-48)*** – Modify the first sentence in the Assumption column for Bioretention Soil Infiltration Rate to "For imported City of Seattle landscape or turf bioretention soil per COS specification 9-14, rate is **3** inch per hour."

Table 2. Determination of Average Permeability Rate for Design with SPU's Bioretention Soil Specification

Report Reference	Project Reference	Sample ID	Organic Content (%)	Percent Compost (volume)[1]	Percent Aggregate (volume)[1]	% Fines[1]	Relative Compaction[1]	Average Permeability (in/hour)
January 06	SPU Testing - Pinehurst	65/35		35	65		80	9.3
January 06	SPU Testing - Pinehurst	65/35		35	65		85	4.2
February 07	WSU Testing	Green Earth Screen Sand	9.6	40	60	2.4	85	13
February 07	WSU Testing	Fred Hill	8.3	40	60	4.6	85	1.3
February 07	WSU Testing	Miles Utility Sand	8.9	40	60	3.7	85	5.6
March 07	High Point Field Test #1		4-8	30-35	65-70	<3	85	4.2
April 07	High Point Field Test #2		4-8	30-35	65-70	<3	85	6.1
Average								**6**

1. Specification requires 1 part compost, 2 part aggregate, 2-5% fines, and 85% compaction

WATER QUALITY TREATMENT
SPU's code and Ecology's Western Washington Stormwater Management Manual both require bioretention soils to meet the following criteria to be considered appropriate for treatment:

1. Clay content < 5%;
2. Minimum organic content of 10% by dry weight;
3. Short-term, minimum infiltration rate of 1.0 inches/hour at 80% compaction; and
4. pH between 5.5. and 7.0.

1. Based on the SPU bioretention soil specification, **the requirement for fines is between 2-5%**, therefore, the bioretention soil meets the first requirement stated above.

2. SPU's bioretention soil specification for **both the landscaped and turf** soil requires an organic content between **8-10% dry weight. This is based on the research that Hinman (2008) completed and was accepted by Ecology.**

3. Based on the values shown in Tables 2, **SPU is confident that the bioretention soils produced using SPU's bioretention soil specification will meet Ecology's required minimum of 1 in/hour at 80% compaction.**

4. The pH of the final soil mix has not been tested and the bioretention soil mix only specifies a pH requirement for the compost, which is between 5.5 and 8.0

Currently, Ecology does not specify a minimum cation exchange capacity (CEC) requirement for bioretention soils, however, it does required at least 5 meq/100 gm dry soil for native soils that are used for treatment. SPU has done limited CEC testing of its bioretention soils and would like to share this information. CEC testing completed on April 5, 2004 for the Engineered and Bioretention Soils used in the Broadview Green Grid Natural Drainage System project (laboratory report attached) found that these soils had a CEC of 10 and 9.6 meq/100 gm, respectively. The Engineered Soil contained 30-35% compost and the Bioretention Soil contained 33% compost. The percent compost is consistent with our current soil specification, therefore, we are confident that our bioretention soils will have sufficient CEC to provide treatment. **In addition, Hinman (2008) has also done CEC testing on bioretention soils that are consistent with SPU's specification and found that they all exceeded Ecology's requirement.**

<u>Revisions to the October 10, 2008 Stormwater Manual Submittal – Volume 3, Chapter 5</u>
The revisions below are recommended to the Stormwater Manual Submittal that went to Ecology on October 10, 2008.

- ***Section 5.8.4.2 Imported Soil Requirements for Bioretention Systems (p.5-76)*- Add following the end of the first sentence "Using Seattle's soil specification produces a soil with a CEC =5 meq/100 grams of dry soil; 8-10 percent organic matter content, 2-5 percent fines; and a maximum of 12 inches per hour initial (measured) infiltration rate."**

I hope this provides the information you need. The modeling recommendations above are approximate values, and it should be recognized that when dealing with materials with inherently variable properties, there is never a single value that will always hold true.

Appendix A

SPU Bioretention Soil Specification

7-21 BIORETENTION SOIL

7-21.1 DESCRIPTION

Section 7-21 describes work consisting of the installation of Bioretention Soil in turf and landscape areas intended to receive surface runoff for infiltration.

7-21.2 MATERIALS

Materials for Bioretention Soil will be specified in the Contract and consist of one or more of the following:

Landscape Bioretention Soil	9-14.1(3)B
Turf Bioretention Soil	9-14.1(3)C

7-21.3 CONSTRUCTION REQUIREMENTS

7-21.3(1) GENERAL

Bioretention soil shall be protected from all sources of additional moisture at the Supplier, in covered conveyance, and at the Project Site until incorporated into the Work. Soil placement and compaction will not be allowed when the ground is frozen or excessively wet, or when the weather is too wet as determined by the Engineer.

When the Contract specifies testing by a Contractor provided testing laboratory, the laboratory must be an STA, AASHTO or ASTM or other designated recognized standards organization accredited laboratory with certification maintained current. The laboratory must be capable of performing all tests to the designated recognized standards specified, and will provide test results with an accompanying Manufacturer's Certificate of Compliance.

7-21.3(1)A SUBMITTALS

At least 10 Working Days in advance of construction, the Contractor must submit to the Engineer for approval:

1) A 10-pound minimum sample of mineral aggregate (Sections 9-03.2(2) and 9-03.2(3), as applicable);

2) A 10 pound sample of mixed Bioretention Soil (Sections 9-14.1(3)B and 9-14.1(3)C, as applicable);

3) A 10 pound minimum sample of compost (Section 9-14.4(9));

4) Grain size analysis results of mineral aggregate performed in accordance with ASTM D 422, Standard Test Method for Particle Size Analysis of Soils;

5) Quality analysis results for compost performed in accordance with Seal of Testing Assurance (STA) standards, as specified in Section 9-14.4(9);

6) Organic content test results of mixed Bioretention Soil. Organic content test shall be performed in accordance with Testing Methods for the Examination of Compost and Composting (TMECC) 05.07A, “Loss-On-Ignition Organic Matter Method”.

7) Modified Proctor compaction testing of mixed Turf Bioretention Soil, performed in accordance with ASTM D 1557, Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort;

8) A description of the equipment and methods proposed to mix the mineral aggregate and compost to produce Bioretention Soil;

9) Permeability or hydraulic conductivity testing of the Bioretention Soil, performed in accordance with ASTM D 2434, Standard Test Method for Permeability of Granular Soils. For the Landscape Bioretention Soil assume a relative compaction of 85 percent of Modified maximum dry density (ASTM D 1557);

10) Provide the following information about the testing laboratory(ies):

    1. name of laboratory(ies) including contact person(s),
    2. address(es),
    3. phone contact(s),
    4. e-mail address(es);
    5. qualifications of laboratory and personnel including date of current certification by STA, ASTM, AASHTO, or approved equal.

7-21.3(2) BIORETENTION SOIL CONSTRUCTION

Contractor shall not start bioretention construction until the site draining to bioretention area has been stabilized and authorization is given by Engineer.

At the locations shown on the Drawings, excavate, grade, and shape to the contours indicated to accommodate placing of Bioretention Soil to the thicknesses required. Dispose of excavated soil or reuse elsewhere as the Contract or Engineer will allow. Scarify the subgrade soil a minimum of 2 inches deep where slopes allow, as determined by the Engineer prior to placing Bioretention Soil.

Mixing or placing Bioretention Soil will not be allowed if the area receiving bioretention soil is wet or saturated or has been subjected to more than ½-inch of precipitation within 48-hours prior to mixing or placement. Engineer shall have final authority to determine if wet or saturated conditions exist.

Place Landscape Bioretention Soil loosely. Final grade shall be measured only after the soil has been water compacted, which requires filling the cell with water, without creating any scour or erosion, to at least 1 inches of ponding. If water compaction is not an option, final grade shall be measured at X inches above the grade specified on the plans to allow for settling after the first storm. X shall be calculated by depth of soil x 0.85 and rounded up to the nearest whole number.

Place Turf Bioretention Soil in loose lifts not exceeding 8 inches. Compact Turf Bioretention Soil to a relative compaction of 85 percent of Modified maximum dry density (ASTM D 1557), where slopes allow, as determined by the Engineer. Where Turf Bioretention Soil is placed in the 2-foot road shoulder, compact to a relative compaction of 90 percent of Modified maximum dry density (ASTM D 1557).

7-21.4 MEASUREMENT

Bid items of Work completed pursuant to the Contract will be measured as provided in Section 1-09.1, Measurement of Quantities, unless otherwise provided for by individual measurement paragraphs here in this Section.

Measurement for Bioretention Soil Construction will be by the cubic yard.

7-21.5 PAYMENT

Compensation for the cost necessary to complete the work described in Section 7-21 will be made at the Bid item prices Bid only for the Bid items listed or referenced as follows:

1. "Bioretention Soil Construction" per cubic yard.

The Bid item price for "Bioretention Soil Construction" shall include all costs for the work necessary to furnish, place, compact, excavate, grade, shape, mix, dispose of, and as necessary.

9-03.2 MINERAL AGGREGATES FOR BIORETENTION SOIL

9-03.2(1) GENERAL

Mineral aggregate shall be free of wood, waste, coating, or any other deleterious material. All aggregate passing the No. 200 sieve size shall be non-plastic.

9-03.2(2) MINERAL AGGREGATE FOR TURF AND LANDSCAPE BIORETENTION SOIL

Mineral aggregate for Turf and Landscape Bioretention Soils shall be analyzed by an accredited lab using #200, #100, #60, #40 and #20. #10, #4, 3/8 inch and 1 inch sieves, and meet the following gradation:

Sieve Size	Percent Passing
3/8″	100
No. 4	95 - 100
No.10	75 - 90
No. 40	25 - 40
No. 100	4 - 10
No. 200	2 - 5

Efforts should be made to have the mineral aggregate for Turf and Landscape Bioretention Soils meet the following gradation coefficients: Coefficient of Uniformity ($C_u = D_{60}/D_{10}$) equal to or greater than 6; and Coefficient of Curve ($C_c = D_{30}^2/D_{60}D_{10}$) greater than or equa1 to 1 and less than or equal to 3.

9-14.1(3) BIORETENTION SOIL

9-14.1(3)A GENERAL

Bioretention Soil shall be a well blended mixture of mineral aggregate and compost measured on a volume basis.

9-14.1(3)B LANDSCAPE BIORETENTION SOIL

Landscape Bioretention Soil shall consist of 2 part compost by volume meeting the requirements of Section 9-14.4(9) and 3 parts mineral aggregate meeting the requirements of Section 9-03.2(3). The mixture shall be well blended to produce a homogeneous mix. Efforts should be made to attain organic matter content as close to 8 to 10 percent as possible, with the final mix to be determined by the engineer based on samples and test results submitted.

9-14.1(3)C TURF BIORETENTION SOIL

Turf Bioretention Soil shall meet the requirements of section 9-14.1(3)B.

9-14.4(9) COMPOSTED MATERIAL

Compost products shall be the result of the biological degradation and transformation of Type I or III Feedstocks under controlled conditions designed to promote aerobic decomposition, per WAC 173-350-220, which is available at http://www.ecy.wa.gov/programs/swfa/compost. Compost shall be stable with regard to oxygen consumption and carbon dioxide generation. Compost shall be mature with regard to its suitability for serving as a soil amendment or an erosion control BMP as defined below. The compost shall have a moisture content that has no visible free water or dust produced when handling the material.

Compost production and quality shall comply with Chapter 173-350 WAC, and meet the following physical criteria:

1. Compost material shall be tested in accordance with Testing Methods for the Examination of Compost and Composting (TMECC) Test Method 02.02-B, “Sample Sieving for Aggregate Size Classification”.

   Compost shall meet the following:

	Min.	Max.
Percent passing 1”	99%	100%
Percent passing 5/8”	90%	100%
Percent passing 1/4”	40%	90%

2. The pH shall be between 5.5 and 8.0 when tested in accordance with TMECC 04.11-A, “1:5 Slurry pH”.

3. Manufactured inert material (plastic, concrete, ceramics, metal, etc.) shall be less than 1.0 percent by weight as determined by TMECC 03.08-A "percent dry weight basis".

4. Organic matter content should be between 45 and 65 percent dry weight basis as determined by TMECC 05.07A, “Loss-On-Ignition Organic Matter Method”.

5. Soluble salt contents shall be less than 6.0 mmhos/cm tested in accordance with TMECC 04.10-A, “1:5 Slurry Method, Mass Basis”.

6. Maturity shall be greater than 80% in accordance with TMECC 05.05-A, “Germination and Vigor”.

7. Stability shall be 7 or below in accordance with TMECC 05.08-B, Carbon Dioxide Evolution Rate”

8. The compost product must originate a minimum of 65 percent by volume from recycled plant waste as defined in WAC 173-350-100 as “Type 1 Feedstocks.” A maximum of 35 percent by volume of other approved organic waste as defined in WAC 173-350-100 as “Type III”, including post-consumer food waste, but not including biosolids, may be substituted for recycled plant waste. The supplier shall provide written verification of feedstock sources.

9. Carbon to nitrogen ratio shall be less than 25:1 as determined using TMECC 04.01 “Total Carbon” and TMECC 04.02D “Total Kjeldhal Nitrogen”. The engineer may specify a C:N ratio up to 35:1 for projects where the plants selected are entirely Puget Sound native species.

10. The Engineer may also evaluate compost for maturity using the Solvita Compost Maturity Test at time of delivery. Compost shall score a number 6 or above on the Solvita Compost Maturity Test.

The compost supplier will test all compost products within 90 calendar days prior to application. Samples will be taken using the Seal of Testing Assurance (STA) sample collection protocol. (The sample collection protocol can be obtained from the U.S. Composting Council, 4250 Veterans

Memorial Highway, Suite 275, Holbrook, NY 11741 Phone: 631-737-4931, www.compostingcouncil.org). The sample shall be sent to an independent STA Program approved lab. The compost supplier will pay for the test. A copy of the approved independent STA Program laboratory test report shall be submitted to the Contracting Agency prior to initial application of the compost. Seven days prior to application, the Contractor shall submit a sample of each type of compost to be used on the project to the Engineer.

Compost not conforming to the above requirements or taken from a source other than those tested and accepted shall be immediately removed from the project and replaced at no cost to the Contracting Agency.

The Contractor shall submit the following information to the Engineer for approval:

1. A copy of the Solid Waste Handling Permit issued to the supplier by the Jurisdictional Health Department as per WAC 173-350 (Minimum Functional Standards for Solid Waste Handling).

2. The supplier shall verify in writing, and provide lab analyses that the material complies with the processes, testing, and standards specified in WAC 173-350 and these specifications. An independent STA Program certified laboratory shall perform the analysis.

3. A list of the feedstock by percentage present in the final compost product.

4. A copy of the producer’s STA certification as issued by the U.S. Composting Council.

Acceptance will be based upon a satisfactory Test Report from an independent STA program certified laboratory and the sample(s) submitted to the Engineer.